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Proposal for radiographic evaluation in materials that don´t possess standardized acceptance criterion

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Abstract

This work discusses the application of the Non Destructive Testing (NDT) in new materials or in materials that don´t possess standardized acceptance criterion. In this way, the central theme is the action to be taken when the material to be inspected presents any kind of defect indication or simply, one non homogeneity. As support for the discussion was used the radiographic inspection in samples made in Carbon-Carbon (C-C) for treating of a material of a great interest in the aerospace sector, very used in rocket nozzles and, in the same time, presents a difficult attainment and very high price. The Carbon-Carbon works in an extremely aggressive ambiance where the pressure and temperature are very high and any defect in material tends to propagate and it is sufficient to conduct a spatial mission to failure. It is a single failure point. As result of this work, will be presented a methodology that can come to be applied, in similar cases, because it seeks to avoid the common practice of rejection material that presents an imperfection indication without the proven of its criticity.

1. Introduction

The constant discovered and introduction of new materials in the most several types of products impose a considerable challenge for the area of Non Destructive Testing that is the attainment of acceptance criteria for the new tested material. This fact has a special importance in the aerospace sector that it is recognized as holder of great amount of products with innovations and technologies of last generation incorporated.

In this context, the term-structural materials, such as the composites Carbon-Carbon (C-C) have countless applications in the aerospace sector for present good resistance to the thermal shock, low coefficient of expansion thermal, high mechanical properties at high temperatures, a great value of thermal conductivity besides possess low specific mass

[1]. They are used in thermal protections of hypersonic vehicles, rocket nozzles, aircraft brakes and other applications.

The composites C-C belongs to the family of materials that have a carboneous matrix reinforced for fibers of carbon [2]. Those materials are obtained by the composition of a reinforcement (pre forming), distributed according to space arrangements (figure 1) in the matrix of the carbon. The number of directions, follow the architecture of the pre forming, is directly linked to the isotropy of the material to be obtained. It means that as larger the number of directions as larger will be its isotropy [3].

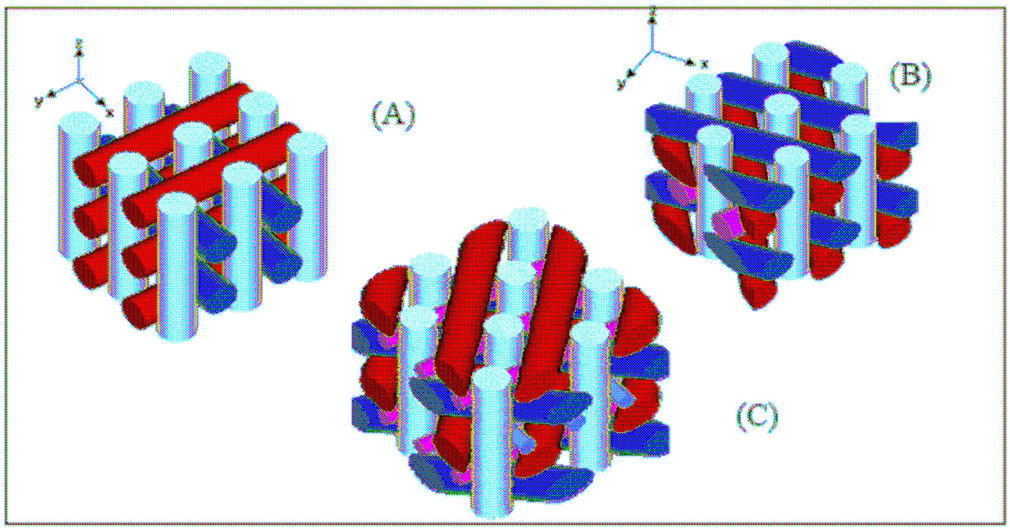

Figure 1. Preforming examples. (A) Tri-directional (3D) orthogonal, (B) Tetra-directional (4D) and (C) Penta-directional (5D).

For this work, the composite Carbon-carbon was chosen by being a plenty example significant for discussion. One of their applications happens how insert of rocket nozzle throat (figure 2) where the atmosphere generated by the expulsion of the gases originating from of the motor-rocket combustion camera, is highly aggressive, being characterized by high temperatures (superior values to 2000^{o}C) and important thermal flows.

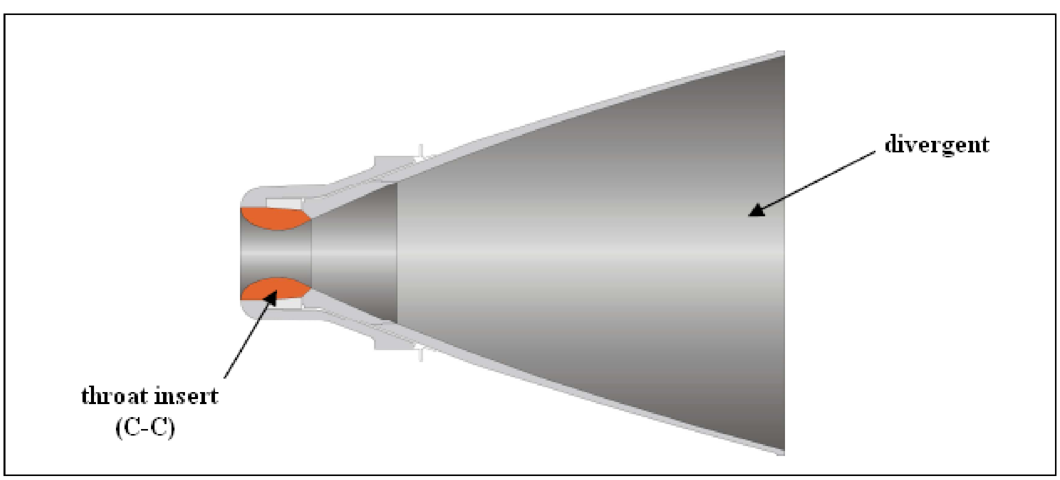

Figure 2. Typical outline of a rocket nozzle.

The wear of that item, for minor that is, alters the flow of the exit of gases and consequently the thrust supplied by the rocket motor (figure 3). It is therefore, a single failure point and, being like that, exhausting controls are made to assure that all of the requirements and characteristics of the material will be present in the item in subject.

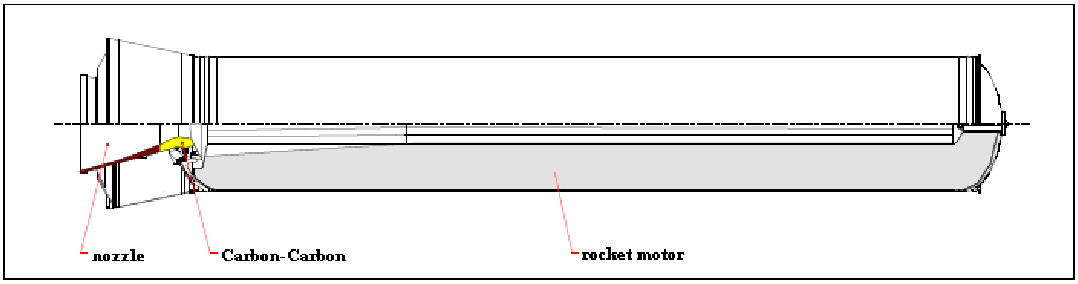

Figure 3. Typical outline of a rocket motor.

There are more than a hundred C-C composites materials that were developed in the last four decades [(4)]. These composites are differed in terms of the types of constituents (fiber and matrix), the number of orientations of the fibers and the production process used.

Researches and developments, seeking the acquisition of the technique of obtaining of those composites, are being driven in approximately 22 nations in the world, fact that indicates the great potential of use of those materials. However, few countries retain the knowledge and the production technology and the larger producers are the United States of America, France and Russia. Smaller amounts they are, also, produced in England, Germany and Japan.

This way, the price for its acquisition is high and its attainment is difficult, because the production of those countries go almost all to supply its internal market. As consequence, the delivery periods are very long and every rejection in a receiving inspection conduct sensitive consequences to the holy program.

2. Importance of NDT

A simple flaw in a component manufactured in composite C-C, just as the nozzle throat insert conducts the space mission (a sounding rocket or a satellite launcher vehicle) to the failure. The nozzle throat is, therefore, a single failure point and, this way, several controls are made to guarantee its structural and functional integrity. Like this, the raw material for the production of the component must be approved for use with the guarantee of good performance.

Non Destructive Testing is applied to make possible the knowledge of the real conditions (verification of flaws, imperfections, inclusions) of the item that will be integrated in the space vehicle. That grants to Non Destructive Testing a fundamental importance.

Due to the porosities characteristics and electric resistance present in the composites C-C, is possible, for their inspection, the use of the technique of X-ray. The density of the carbon-carbon varies between 1.85 to 2.0 and the radiography supplies a vision of the arrangement of the rods of fiber of carbon disposed in positions pre-determined in the carboneous matrix and like this there is the possibility to verify any present defect.

For the verification of the mechanical properties, as the characterization of the resistance in compression, standardized testing can be executed in a perfect way in bodies of test of carbon-carbon. However, the results of such tests will only have value if the tested samples don´t have any defect to influence the resistance of the material.

Of this sort, the inspection for X-ray in the bodies of test, before they begin to be tested has a vital importance because it can **validate** the obtained results. In other words, any variation founded in the result of the mechanical testing cannot be attributed to internal defects in the material of the bodies of test. In other hand, analysis of the dispersion founded in the accomplished tests - characteristic fact in the composites materials - it can accept as a common interval, when in fact, this interval would be being influenced by pieces that contained discreet defects.

3. The proposed methodology

3.1 Methodology

The proposed methodology consists of introducing defects, in bodies of test made in C-C material (3D orthogonal) of a certain dimension that they are detected in the Non Destructive Testing applicable (X-ray) and, through a standardized testing, to verify the influence of this defect size in the property discussed.

For the case of the carbon-carbon composite, the property to be verified is the compression resistance whose testing is standardized by ASTM C 695-91.

They were tested in compression axial 4 bodies of test without any defect and verified their compression resistance. The results, the average (M1) obtained and the standard deviation (DP1), are presented in the Table 1. It is important to say that such results only possess value because they were obtained of bodies of tests that passed by X-ray inspection and the total absence of defects was verified.

In the sequence, they were tested, in axial compression, 3 bodies of test with a single defect. A passing hole with diameter of 0.5 mm (detected in the X-ray) was made transversally to the specimen and its medium resistance in compression was verified. The results, the average (M2) obtained and the standard deviation (DP2), are presented in the Table 1.

Finally, they were tested more 3 bodies of test, in axial compression, also with a single defect. A passing hole with diameter of 0.8 mm (detected in the X-ray) was made transversally to the specimen and its medium resistance in compression was verified. The results, the average (M3) obtained and the standard deviation (DP3), are presented in the Table 1, also. Again, it is important to say that that these bodies of test possess just the defect introduced willfully.

3.2 Definition of the size of the defects

The size of the defects to be introduced was defined having in mind the sensibility of the test. In this case, the radiographic technique has to demonstrate the minimum sensibility that is around 2% of the thickness to be inspected [5].

At the same time, the objective is to determine when a defect begins to alter the property that this being studied, what only will be to happen with larger defects. When this is the intention, it should be planned testing with a rate of growing of defects size.

4. Presentation of the results

4.1 Results obtained

The results of the accomplished testing are in the Table 1, and they were obtained with the suitable equipments below.

- X-ray Seifert Eresco, 225 kV, constant potential, focal point size = 5.6 mm
- Testing machine Otto Wolpert - 20phz728

Table 1. Results obtained in the compression testing

Body of Test Identification	Defect	Rupture (kN)	Average	Standard Deviation
1	without	22		
2	without	21	21.3	1.7
3	without	19		
4	without	23		
5	0.5 mm hole	25		
6	0.5 mm hole	22	23.7	1.5
7	0.5 mm hole	24		
8	0.8 mm hole	22		
9	0.8 mm hole	21	21.3	0.6
10	0.8 mm hole	21		

The Figure 4 presents the bodies of test without defect, the bodies of test that had a passing hole with diameter of 0.5 mm and with diameter of 0.8mm, and the bodies of test after compression testing.

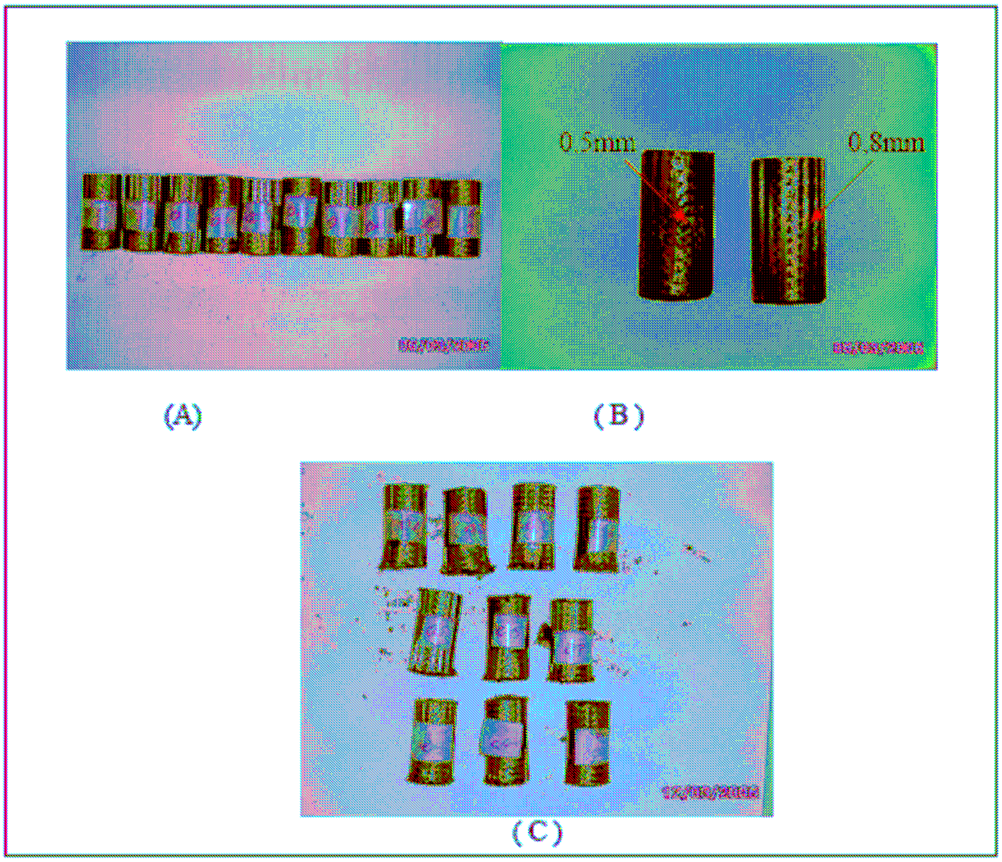

Figure 4. (A) The bodies of test used before the compression testing, (B) types of bodies of test used and (C) the bodies of test after the compression testing realized.

4.2 Comments

i) If a unique group of data is considered, the lot would have as a rupture tension in compression, considering only 1 standard-deviation, the interval of 20.3 kN to 23.7 kN. The lot with larger defect (hole of 0.8 mm) obtained as result, the interval of 20.7 kN to 21.9 kN, being completely inside of the general lot;

ii) If it was just considered the group of data without any defect, the lot would have as tension of rupture in compression, considering only 1 standard deviation, the interval of 19.6 kN to 23.0 kN. The lot with larger defect (hole of 0.8 mm) would be still completely inside of the general lot;

iii) The authors will continue the tests to obtain statistical meaning in the results.

5. Conclusion

The use of new materials is, and it will continue being, common in the aerospace sector and, in many cases are not much probable that it is had a standardized acceptance criterion for emission of a decision in a report about the material of interest.

The obtained results indicate that the sensibility of the radiographic testing is enough to allow the evaluation of the conformity of C-C in relation to the compression resistance and that, the proposed methodology, allows a first approach for the solution of the problem avoiding rushing hand of the rejection as first option when any defect is found.

As in the great majority of the practical situations, the time and the readiness of resources for the accomplishment of a larger number of tests is scarce and this has direct influence in the observed dispersion around the medium value but, in compensation, it is obtained an integral use of the results because all of the samples were validated by the Non Destructive Testing before they be submitted to the testing of the studied property.

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